PAPER • **OPEN ACCESS**

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To cite this article: I I Shanin 2019 *IOP Conf. Ser.: Mater. Sci. Eng.* **560** 012042

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IOP Conf. Series: Materials Science and Engineering **560** (2019) 012042 doi:10.1088/1757-899X/560/1/012042

Modeling of technological processes at enterprises of timber processing industry

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Abstract. Dynamic development of the Russian market of timber products and tightening of technological advantages give particular relevance to the use of advanced technological methods to optimize the production process. It will lead to an increase in the competitiveness of enterprises. Improvement of approaches to managing the technological development of enterprises, their provision with various types of innovative resources and technologies for the optimal use of all reserves of industrial enterprises is of particular importance in the context of the formation of effective areas of production system technological development. The following should be noted in terms of the development of woodworking equipment production. 23 factories produced 30–35 thousand woodworking machines and lines per year in the Russian Federation in the early 1990s. Currently, according to Rosstat, only 4–6 thousand units of woodworking equipment are manufactured. Machine-tool enterprises sharply reduced output or ceased to exist since most of domestic woodworking machines turned out to be uncompetitive in comparison with the equipment of leading foreign companies. In recent years, there has been an increase in the tendency to reduce the relative share of consumption of domestic woodworking equipment on the Russian market. Share of domestic equipment decreased from 29 % to 7 % according to expert estimates in the period from 2000 to 2017. Accordingly, imported equipment makes more than 91 % on the market. The article has reviewed and analyzed furniture enterprises of timber industry complex connected with woodworking process.

1. Introduction

In the 1980s, the furniture industry of the Soviet Union was distinguished by a large proportion of manual labor, insufficiently high qualification of employees and high wear and tear of equipment. As a result, manufactured products did not always meet the needs of the consumer in terms of volume, quality, and technological parameters. Another problem was absence of enterprises producing special equipment for furniture factories. The situation has changed with the introduction of the economic reforms of the 1990s. A large selection of products, materials, components and technologies has been formed. And the furniture industry successfully overcame even the crisis of the late 1990s, without losing highly qualified personnel and production potential. The furniture market was actively developing in the period from 2000 to 2008. Sales of products increased by 23 % annually (taking into account price changes). If there was a significant decline in production due to the crisis in 2009-2010, the volume of furniture production exceeded even the pre-crisis level in 2011-2012. However, the country's accession to the WTO has led to an increase in the share of cheap imports. As a result, the main competitive advantages of the Russian furniture (low material cost and low labor costs) have lost their strength. Since

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2014, everything has returned to its place, when foreign suppliers have become uncompetitive due to the rising dollar. In 2017, the share of domestic producers in the domestic market amounted to more than 80 % by volume and up to 63 % in terms of value. Export of furniture from the Russian Federation has been kept low since the beginning of the new century, significantly inferior to exports. In 2015, the share of the Russian Federation in the global furniture production was less than 1 %. By comparison, the share of America is 27 %, Japan, Germany and Italy – 9 %, and China – 7 %. About 5-6 thousand of enterprises are engaged in production of wooden furniture in Russia. Only fifteen of these have annual turnover exceeding 1 billion rubles. These enterprises make about a half of the production. About five hundred companies have a turnover of 0.3-1 billion rubles and belong to medium-sized businesses. Furniture industry is the only segment of the timber industry, whose centers are distant from the main areas of raw materials production. Significant amounts of imported analogues of forestry equipment purchased from abroad create the problem of ensuring the maintenance and operation of these machines and mechanisms for the Russian timber industry complex [1, 2].

The wear of high-precision clamping and guiding elements of machine tools, failure of components, often made to be non-separable and which are not subjects to repair require new import purchases associated with time loss and excessive additional costs.

Along with these problems, strong government support is needed for the production of forestry machinery and equipment, including those aimed at preventing and extinguishing forest fires. Only strong support at the state level can provide a qualitative breakthrough not only in the direction of timber processing equipment production for Russian forest needs at affordable prices, but also in the development of the most popular innovative models of machines and mechanisms in timber processing complex [3]. The development of machine building direction enables one to bring the corresponding segment of the domestic market of equipment and mechanisms to the new level. It will allow creating conditions for increasing competitive advantages and further development of timber industry complex [4, 5].

2. Materials and methods

Having conducted a study of the problems and practical application of technological innovations in enterprises, the author set a task for developing a methodology aimed at improving the approaches to modeling technological processes in timber industry enterprises. The developed technique has a course aimed at introducing new technological solutions into the production process, characterized by the improvement of production technologies, the choice of forms, tools and methods for the technological development of enterprises, based on the established indicators and criteria for evaluating the technological development of enterprises [6, 7].

Introduction of the most effective technologically innovative solutions is the main tool for technological development control in enterprises (in terms of saving resources). The author has conducted a simulation based on the improvement of technological business processes on the use of current assets, production and labor resources, machinery and equipment. Modeling is carried out using the method of conducting system analysis and building a model, based on the method of least squares, using an epignosis forecast. The analysis uses statistical data of financial and economic activities of enterprises for previous periods. The author models the effective distribution of technological capital in the structure of the use of timber resources for the purpose of their most effective use [8, 9].

3. Results and discussion

The study has identified three enterprises of the furniture industry L_1, L_2, …, L_n for T period of time, consisting of n production and economic years t_i (i=1,2,…, n), while $T = \sum_{i=1}^{k} t_i$ to identify the most effective technologically innovative solutions. Investment funds A have been issued for the technological development of enterprises by the beginning of the period T. It is necessary to finance all the elements of the production system of enterprises at the beginning of each reporting period.

There are parameters of the initial state of the Y_0 system, which are characterized by the number of currently attracted investment funds in the technological development of the enterprise. They are determined by the final Y_k value. These indicators are characterized by the total additionally invested amount of technological capital *P*, so that the total summed income *U* of the total production system of the enterprise has values at the maximum level to the final value of the period *T*.

It is necessary to define *xij* sum that is allocated at the beginning of the i-th period to the *j-th* enterprise (*i = 1,2, ..., n; j = 1,2, ..., k*). Let us suppose that at the *i-th* stage the technological means were fully distributed, i.e. certain technological resources of D_i were selected, consisting in the fact that, at the beginning of the *i-th* year, L_1 entreprise received funds x_{i1}, L_2 entreprise received funds x_{i2}, etc. In this case, the vector $D_i = (x_{i1}, x_{i2}, ..., x_{in})$ is characterized by the distribution of funds at the *i-th* stage. The volume of all invested technological resources in *n* steps will be expressed in the system of vector by *k*-dimensional vector space [10, 11].

$$\begin{pmatrix} D_1 = (x_{11}; x_{12}; ...; x_{1k}), \\ D_2 = (x_{11}; x_{22}; ...x_{2k}), \\ ..... \\ D_n (x_{k1}; x_{k2}; ...x_{kn}). \end{pmatrix}. \quad (1)$$

The total profitability for *n* years depends on the aggregate of invested funds in technological development, i.e. acts as a function of $D_1, D_2, ..., D_n$:

$$U = U(D_1, D_2, ..., D_{kn}), \quad (2)$$

The main task is the following: the necessary technological solution is chosen at each level, so that the totalized yield from all technological investments of enterprises is the maximum one. This formulation of the problem is solved by combining all the steps. *U* function (as a function dependent on control element) should be considered at each level:

$$U = (x_{11}, x_{12}, ..., x_{1n}; x_{21}, x_{22}, ..., x_{2k}; ...; x_{n1}, x_{kn2} ..., x_{kn}). \quad (3)$$

Thus, we obtain the function of the set of variables. When solving the problem, it is necessary to find such a set of values of the arguments x_{ij}, for which the function *U* under consideration needs to get the maximum value. This is the solution to the problem. Finding the partial derivatives of the function *U* for all arguments, it is necessary to equate them to zero and solve the system of equations $\frac{\partial U}{\partial x_{ij}} = 0$, getting x_{ij} values for which the function *U* has the necessary maximum [12, 13].

X funds are provided for three years for the purposes of development of technological processes of several production directions by each enterprise. The amount of funds *y,* provided to the first direction, makes it possible to obtain profitability of $\varphi(y) = 0.75y^2$ in one calendar year and reduced to $\varphi(y) = 0.75y$. The amount of *x-y* funds provided for the second direction makes it possible to increment profitability $\xi(x-y) = 2(x-y)^2$ in one calendar year and reduced to $p(x-y) = 0.3(x-y)$.

It is necessary to allocate the resources between production areas for the planned years to have the maximum profitability. It is necessary to divide the period into 3 stages, even when considering a continuous process. *X* and *y* values will be marked by indices at all three stages for a visual overview.

We start the process of finding the optimally needed solution from the 3rd stage. First it is necessary to distribute the balance of investment funds x_2. For this, it is necessary to determine the permissible optimal value of the function y_3. We obtain the formulation of expressions for functions:

$$g_3(x_2, y_3) = \phi(y_3) + \xi(x_2 - y_3) = y_3^2 + 2(x_2 - y_3)^2, \quad (4)$$

$$f_3(x_2) = \max_{0 \le y_3 \le x_2} \left\lfloor y_3^2 + 2(x_2 - y_3)^2 \right\rfloor. \quad (5)$$

We find the value of y_3 using the method of differential calculations. The function in square brackets on the interval $[0, x_2]$ takes the maximum optimal value. It is necessary to take into account that x_2 is a constant value at the 3rd stage, and then we get [14, 15]:

$\frac{d}{dy_3} g_3(x_2, y_3) = 0$; $2y_3 - 4(x_2 - y_3) = 0$; $y_3 = \frac{2}{3}x_2$;

$\frac{d^2}{dy_3^2} g3(x_2, y_3) = 6 > 0$; $g3(x_2, \frac{2}{3}x_2) = \frac{2}{3}x_2^2$.

$y_3 = (2/3)x_2$ value is an extremum of the minimum.

The values of the extrema of the function at the end of the segment are [0, x_2]: $g_3(x_2, y_3) = 2x_2^2$ at y_3=0,

$g_3(x_2, y_3) = x_2^2$ at y_5=x_4.

Considering $2x_2^2 > x_2^2 > (2/3)x_2^2$, the extremes of the function $g_3(x_2, y_3)$ will take the maximum values on the entire interval [$0, x_2$], at which $y_2 = 0$. Based on this we get $f_3(x_2) = 2x_2^2$. Consequently, the maximum yield at the final stage can be achieved provided that the entire amount of the remaining funds is allocated for the development of the second production direction at the beginning of this stage.

Alternately, we find the optimal distribution of funds in the first two stages.

The functional equation system for the second stage is fixed:

$$f_2(x_1) = \max_{0 \le y_2 \le x_1} \{g_2(x_1, y_2) + f_3(x_2)\} = \max_{0 \le y_2 \le x_1} \{y_2^2 + 2(x_1 - y_2)^2 + 2x_2^2\}, \quad (6)$$

provided that $x_2 = 0.75y_2 + 0.3(x_1 - y_2)$, we get:

$$f_2(x_1) = \max_{0 \le y_2 \le x_1} \{y_2^2 + 2(x_1 - y_2)^2 + 2[0.75y_2 + 0.3(x_1 - y_2)]^2\}.$$

With the made decision and the obtained values, we conclude that the optimal management of the provided investment resources is determined by the following circumstances: investment funds should be sent only to the first production line during the first period, then (over the next two periods) it is necessary to invest only in the second development of the production direction. The obtained optimal management solution is true for all $x > 0$, therefore, not considering for specific value of x, the amount of funds subjected to redistribution when planning for each year is determined.

For the effective use of investment funds between production areas for the development of enterprises the author proposes to calculate this model for the following enterprises: Grafskaya Kukhnya LLC, Angstrem LLC PC, Mebel Chernozemya LLC HC. We take for the condition that the same amount of investment capital of 160 million rubles is provided for each enterprise, based on the structural-functional system of equations for the first and second directions. The results of the calculations are given in table 1.

The distribution of investment capital should be carried out according to the ratios of the functions obtained earlier, splitting it into several stages across all enterprises. For Grafskaya Kukhnya LLC furniture company, the calculation for the distribution of investment capital will be as follows.

1st stage. Investment funds are provided only for the first production direction of the enterprise. Thus:

f1(40)=16, f1(80)=30, f1(120)=48, f1(160)=64.

2nd stage. Investment funds are provided for the first and second direction of enterprise development:

$$f_2(x) = \max\{q_2(x_2) + f_1(x - x_2)\}. \quad (7)$$

Then at x=40, $f2(40) = \max(16 + 0, 0 + 22) = \max(16, 22) = 22$,

at x=80, $f2(80) = \max(30, 16 + 22, 38) = \max(30, 38, 38) = 38$,

at x=120, $f2(120) = \max(48, 30 + 22, 16 + 38, 52) = \max(48, 52, 54, 52) = 54$,

at x=160, $f2(160) = \max(64, 68 + 22, 30 + 38, 16 + 52, 82) = \max(64, 70, 68, 68, 82) = 82$.

3rd stage. Investment funds are provided for the next two direction of enterprise development:

$$f_3 x = \max\{q_3(x_3) + f_2(x - x_3)\}. \quad (8)$$

Then at x=40, $f3(40) = \max(22, 24) = 24$,

at x=80, $f3(80) = \max(38, 22+24, 40) = \max(38, 46, 40) = 46$,

at x=120, $f3(120) = \max(52, 38+24, 22+40, 50) = \max(52, 62, 62, 50) = 62$,

at x=160, $f3(160) = \max(82, 52+24, 38+40, 22+50, 78) = \max(82, 78, 78, 72, 78) = 82$.

4th stage. Investment capital of 240 million rubles is provided for the fourth production direction of the enterprise:

At x=160, $f4(160) = \max(126, 106+22, 82+46, 62+60, 46+74, 24+102, 126)$
$= \max(126, 128, 128, 122, 120, 126, 126) = 128.$

Table 1. Means Funds of planned investment in technological development according to the production areas of enterprises.

Provided funds, mln. rubles	Increase in production, one million rubles.			
	Directions of production development of Grafskaya Kukhnya LLC			
	Halls	Bedrooms	Seating furniture	Kitchen sets
40	16	22	24	22
80	30	38	40	46
120	48	52	50	60
160	64	82	78	74
Directions of production development of Angstrem LLC PC				
	Halls	Bedrooms	Kitchen sets	Bedroom furniture
40	32	40	38	40
80	34	80	76	80
120	116	120	118	120
160	160	154	160	160
Directions of production development of Mebel Chernozemya LLC HC				
	Halls	Seating furniture	Kitchen sets	Bedroom furniture
40	28	34	40	38
80	69	80	76	73
120	120	112	120	119
160	157	148	151	160

For Angstrem LLC PC at the 1st stage, investment funds are provided only for the first production direction of enterprise development:

f1(40)=14, f1(80)=24, f1(120)=42, f1(160)=60.

At the 2nd stage, investment funds are provided for the first and second production direction of the enterprise:

at x=40, $f2(40) = \max(14+0, 0+16) = \max(14, 16) = 16$,

at x=80, $f2(80) = \max(24, 14+16, 36) = \max(24, 30, 36) = 36$,

at x=120, $f2(120) = \max(42, 24+16, 14+36, 52) = \max(42, 40, 50, 52) = 52$,

at x=160, $f2(160) = \max(60, 42+16, 24+36, 14+52, 74) = \max(60, 58, 60, 66, 74) = 74$.

At the 3rd stage, investment funds are invested in the second and third production direction of the enterprise's development:

at x=160, $f4(160) = \max(116, 88+22, 74+46, 52+56, 36+84, 16+96, 124)$
$= \max(116, 110, 120, 108, 120, 116, 126) = 124.$

Talking about Angstrem LLC PC, the most optimal option for the distribution of the total investment capital of 160 million rubles is investment in the production direction of the development of kitchen sets. The maximum increase in output is 124 million rubles.

Investment funds are needed to be invested only in the first production direction of development (Mebel Chernozemya LLC HC, the 1st stage). Then:

f1(40)=12, f1(80)=26, f1(120)=44, f1(160)=58.

2nd stage, investment capital is provided for the first and second production direction of the enterprise:

at x=40, f2(40)=max(12+0,0+30)=max(12,30)=30,

at x=80, f2(80)=max(26,12+30,48)=max(26,42,48)=48,

at x=120, f2(120)=max(44,26+30,12+48,60)=max(44,56,60,60)=60,

at x=160, f2(160)=max(58,44+30,26+48,12+60,78)=max(58,74,74,72,78)=78.

3rd stage. The second and third production directions of development are financed. Calculations are performed by the formula:

$$\text{at } x=120,\quad f4(120) = \max(63, 49+12, 39+15, 30+27, 24+32, 15+42, 57) = \max(63, 61, 54, 57, 56, 57, 57) = 63.$$

4. Conclusion

Based on the results of the calculation, it can be concluded that every enterprise has its own optimal options for the distribution of investment funds in order to manage effective development. For Angstrem LLC PC all the investments in the amount of 160 million rubles should be sent for “Kitchen sets” development. For Grafskaya Kukhnya LLC the investments in the amount of 160 million rubles should to be sent for “Seating furniture”, and 80 million rubles - for the development of “Kitchen sets” direction. For Mebel Chernozemya LLC HC all the investment funds (160 million rubles) must be used for “Seating furniture” technological development.

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